HYDRAULIC DEVELOPMENT OF BOW FORT FALLS, ALBERTA, CANADA

BY

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ARMOUR INSTITUTE OF TECHNOLOGY

1920

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development at Bow Fort

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Proposed Hydraulic Development at Bow Fort Falls, Alberta, Canada

A THESIS

PRESENTED BY

William James Wignall

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Acknowledgment

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NOTE

The information and statistics used in this thesis were collected and compiled from the reports and Bulletins published by the Canadian Government, and, as far as possible, a check was made with the reports of the United States Geological Survey.

The following volumes were found to be of valuable assistance as references to general treatment and design.

"Hydrology"	D. W. Wead
"Water Supply Engineering"	A. P. Folwell
"Hydraulics"	Hughes & Safford
"Hydro-Electric Power" Vol. 1	L. Lyndon

HYDRAULIC DEVELOPMENT OF
BOW FORT FALLS
ALBERTA, CANADA

The Bow River is a typical Mountain River, having its head waters in the Rocky Mountains, 6,500 feet above sea level, in the province of British Columbia, 130 miles northwest of Calgary, in the province of Alberta. West of this city it drains an area of 3,138 square miles. It's flow is typical of all mountain streams, subject to sudden variations and greatly influenced by conditions of temperature. During the winter months the flow is much reduced, but in the hot summer months of June and July, the floods occur and the variation of high and low water is very great, it varying from 50,000 cubic feet per second, maximum flood, to 600 cubic feet per second, low water, during December and January, at an observed point. It's total fall from the source to Calgary is 3,470 feet through mountanious regions well adapted to power development. Numerous lakes, and diverging streams

along its course also enhance its value in regard to storage possibilities.

A study of the periodical distribution of precipitation over this region indicates that it is fairly constant both throughout the year and from year to year. At Calgary the lowest recorded annual precipitation occurred in 1892, 7.91 inches being the amount; and in 1902 the maximum occurred, 34.57 inches being recorded. This was over a period of 27 years during which the mean year precipitation was 16.10 inches. Half way between Calgary and the river's source, for the same period, the maximum was 30.59 inches, the minimum 10.32, and the mean yearly precipitation 19.13 inches.

A comparison of the records of precipitation to those that run-off show that the later at times, exceeds the former by as much as 25%. A condition not at all unusual for mountain districts.

The first hydro-electric plant on this river

was located in the city of Calgary where a natural fall in the stream is used and a head of 12 feet is developed. This plant supplies power for lighting and industrial distribution and is assisted by a steam generating plant during periods of low water. This development is not on a very permanent basis and cannot be a very efficient one.

The largest power development upon the river, at present, is located at Horse Shoe Falls, 48 miles west of Calgary where a head of 70 feet is produced. The complete turbine installation has a capacity of 19,500 horse power. Three (3) transmission lines are in operation, one to the city of Exshaw, eight miles away, and the others to Calgary.

The Kananskis Falls plant has just been completed. This is just below the junction of the Kananskis and Bow Rivers, 50 miles west of Calgary where a head of 70 feet is obtained. The turbine capacity of the plant is 11,600

horse power, and power is supplied to Calgary and Exshaw.

The possibility of further development on this river and its tributaries is, owing to the topography, confined in a general way to particular stretches of the river, between Kananskis Falls and Calgary. Those sites most worthy of consideration as feasible developments are as follows:

At the Radnor Site, 27 miles west of Calgary, it would be possible to develop a head of about 44 feet, which would produce approximately 5,200 horse power. Five miles farther west at the Ghost Site, a head of 50 feet is available which would probably give an output of 7,300 horse power. At the Mission Site, 6 miles west of Ghost Site, a net head of 47 feet could be developed, and 6,400 horse power could be produced.

However, the most promising site is that at Bow Fort Falls, 9 miles farther west and 44 miles from Calgary, and its possible development

is herein treated.

After passing the Horse Shoe Falls Power Plant, the river flows between high banks for about three miles, and at very few points in this distance is it possible to get down to water level, the banks being very precipitous and rising to heights of from 40 to 200 feet. Bow Fort Creek empties into the river about half a mile above the site and the perpendicular rock cliffs between these two points are about 50 feet high and 265 feet from side to side.

It is proposed to take advantage of the natural storage facilities by placing the dam at this site, the river filling up the wide and deep channel so formed. The detail study of the proposed development is as follows:

GEOLOGY

The general tilt of the rock at Bow Fort is towards the west and the general characteristics give the impression that there was a fall in the

river here at one time, the cliff having been cut back until all that remains is a slight drop which entirely disappears at high water. The cause of this drop is a ledge of shale banded with limestone extending across the river; and it is upon this ledge that it is proposed to place the dam.

The relative position and depths of the strata is shown in Plate No. 1. It is recommended that in order to obviate any leakage that might develop through the underlying seams,three inch holes be drilled through the rock about 2 feet in front of the face of the dam, 10 feet apart, and to a depth of 40 feet, and a thin cement grout forced into them under pressure.

TOPOGRAPHY

The general topography of the basin and of the site, has already been treated in a general introduction. The contour map, Plate No. 2, indicates the slope of the land from a point be-

low the site to a point above the Horse Shoe Falls Plant, 48 miles up the river, west. To obtain the proposed head of 66 feet, possible by the natural fall of the river, the water above the dam would be backed up to within 2 feet of the tail water of the Horse Shoe Falls Plant,the back water curve having an elevation of 4,010 feet. None of the land that will be flooded at this elevation is occupied at present, nor is it being used for agricultural purposes. The pondage above the dam thus created will be 205.2 acres.

TEMPERATURE

The temperature in the drainage area is one of the great factors influencing the discharge of the river, as has been previously stated. The range is very great, it varying from an absolute minimum of -36 degrees in January to an absolute maximum of + 86 degrees in July. (See mean temperature curves Plate No. 3). During the months of low temperature the discharge is low, while

high temperature corresponds to hig discharge. (See Plate No. 4). Extreme ice conditions are to be expected and provided for. However, it is anticipated that on account of the depth of the river, sheet ice only will be formed and this will prevent the formation of both fragile and anchor ice. To guard against any possible danger, 2 inch pipe racks should be provided at the intake and these heated with steam during period of extreme cold.

RAIN FALL

The precipitation curves shown on Plate No. 5 indicate that the total yearly rain fall for the past nine (9) years has been fairly constant, the average over this period being 18.14 inches with 12.91 inches as a minimum and 23.77 as a maximum. For these nine (9) years the maximum monthly rain fall has invariably occurred during the period from April until August, (the hotter months) and the minimum during the months from December until

March, (the colder months).

In considering the relation of precipitation to run-off, a period known as the water year is made use of instead of the calender year. This period is assumed as extending from October 1st until September 30th for practically all of the water is obtained from the mountains, and from October 1st on, the precipitation in the form of snow is stored in the mountains to be held until the warm sun of the early summer releases it. These freshets occur during May, June and July. From December 1st until April 1st, may be called the low water period, the river during this period being dependent almost entirely upon the discharge of ground water, springs, and other underground sources. Extreme low water may be expected during January and February, after the end of February and throughout March and April, the run-off is increased gradually by the melting snow in the lower parts of the valley, and by May 15th the first of the floods generally appear.

At this time the run-off increases rapidly due to the melting snow on the mountains and to the heavy rain fall which occurs at this time.

The exact relation between precipitation and run-off is not definitely known, but a comparative study of the precipitation and the discharge curves together with a knowledge of the vegetation and stratification indicates that a very small percentage of the rain fall is absorbed as ground water. The land on the water shed is covered with jackpines and with some underbrush. The elevated back water curve caused by ponding the river, will undoubtedly raise the ground water level and this will prove very desirable as a favorable storage factor.

DISCHARGE

Under present conditions of the river, that is without storage, the low water discharge may be expected to go as low as 600 cubic feet per second, though only for short periods. With the

storage contemplated with the dam, it is expected that a minimum flow of 1,500 cubic feet per second will be obtained and it is upon this basis of discharge that the proposed development is based.

As may be seen from the mean monthly discharge curve, Plate No. 6, this is a very conservative estimate, in fact a minimum of 2000-cubic feet per second might easily be obtained. The daily discharge curve shown on Plate No. 4 indicates an absolute minimum of 600 second feet for the period from November 1912 to March 1913, during which time very low water is to be expected. The maximum during these months is 2000 second feet and the average 1100 second feet. This amount, it is to be remembered, is the natural flow of the river and with no storage afforded. The average maximum discharge durint the flood periods, is 10,000 second feet and the maximum observed on the river is 50,000 second feet. The development is designed to take care of this amount, (50,000 second feet). It is necessary to make

provision for this excessive amount on account of the rapidity with which it occurs and the possibility of danger to the plant from the ice that is usually present at flood periods.

The plant at Horse Shoe Falls is already operating under a discharge of 1,500 second feet with ample provision for enlargement made possible by creating additional storage on the Kananskis River which empties into the Bow River three (3) miles above their dam. This future development would also directly increase the discharge at the Bow Fort site and the same provision for additional power units should be made at this place.

STORAGE

The results of the pondage of the 205 acres behind the dam is well indicated by the Ripple diagram Plate No. 7. The discharge as well as the draft by the turbines, in millions of cubic feet, is plotted against the time in months for

a period of a year. These values of discharge are the respective monthly averages during the four (4) years, 1909, 1910, 1911, 1912- which are representative of normal conditions.

The curves show that the flow many times exceeds the amount of water used, except for the months of January to April inclusive. During this time the supply will be drawn from the storage and at no time, during this period, will the draft lower the head over the dam more than 12 feet. As the minimum allowable head for efficient operation is 46 feet, the above figure is well within the safety limit.

DEVELOPMENT

It is proposed to construct at this, the Bow Fort Falls site, a hydro-electric plant in three units of 500 second feet each, with provision for the installation of two (2) or three (3) additional units, as rapidly as further storage possibilities are worked out. The general plan

of the works is indicated on Plate No. 8.

The dam is to be of the vertical back type, spill-way section, rubble concrete. The rock from the excavation from the site being used for rubble. The length of the spill-way is 250 feet and the structure is designed to provide for a crest height of 15 feet. This will discharge 47,600 cubic feet per second and, to provide for the balance of 50,000 cubic feet per second absolute maximum, two 8' x 8' sluice tunnels are constructed through the dam at an elevation of 3956. The sluice gates are to be made of heavy cast iron slabs, strengthened and supported by ribs and arranged to slide in a strong iron frame on the up-stream face of the dam. The sliding surfaces being faced with bronze strips. These gates are to be operated by a hydraulic rams and plungers placed above them on the face of the dam.

This will take care of a total discharge of 51,400 cubic feet per second. The advantage of

this installation is that during the construction of the upper portion of the dam, the water may be diverted through these channels.

The thickness of the dam at the base is 84 feet from the heel to the toe and it has a cross-sectional area of 1,850 square feet. Further details and dimensions of this section are indicated on the drawing, Plate No. 8.

The intakes are to be three, (3), steel pipes set flush with the back of the dam at elevation 3989. They are 13 feet in diameter at the face and taper to 9 feet diameter where they join the riveted steel penstocks. Trash racks of flat rolled steel bars, placed with the flat side parallel with the flow of water, protect the intakes as shown in detail - Plate No. 10.

The Gate house is to be built on the bulwark directly over the intake.

An 8' x 9' tunnel running the length of the dam should be constructed at elevation 3968, with a .01% grade, and a 10' x 10' stair-well built

near the gate house would provide access to this tunnel and permit of regular inspection.

The Power House is to be located 210' down stream from the dam, the water being conducted by the three, (3), 9' riveted steel penstocks. The Power equipped would consist of three (3) Francis turbines, set horizontally, of 4,400 horse power each, with 2,500 K.W. generators mounted on the shaft.

The tail water elevation will be 3944 and the tail race is to be protected from disturbance by a wing retaining wall running 40' down stream from the power house.

CONCLUSION

The constant growing demand for cheap power for Municipal and manufacturing purposes, has made the question of water-power development in Canada one of vital importance. This section of the country is in its youth in the development of natural resources.

Until now, lumbering and mining have been the two principal industries but, with the increasing cost and difficulties of rail transportation, as well as the uncertainty of the coal production and delivery, firms are establishing their paper and other wood product mills in the lumber regions where it is possible to obtain hydro-electric power. At present, their demands far exceed the supply as regards the present installations.

In addition to this one ready market, the cities of Calgary and Exshaw and other nearby mining towns, afford an immediate and needy market. The possibility of the electrification of the railroads through this section is also

under advisement and this too would create an immediate market.

The Canadian government has been very active in investigations along these lines, and has indicated its desire to afford a very earnest co-operation. As a matter of fact, the officials, recognizing the urgent need of these developments have already recommended the installation of several plants, to be owned and operated by the government.

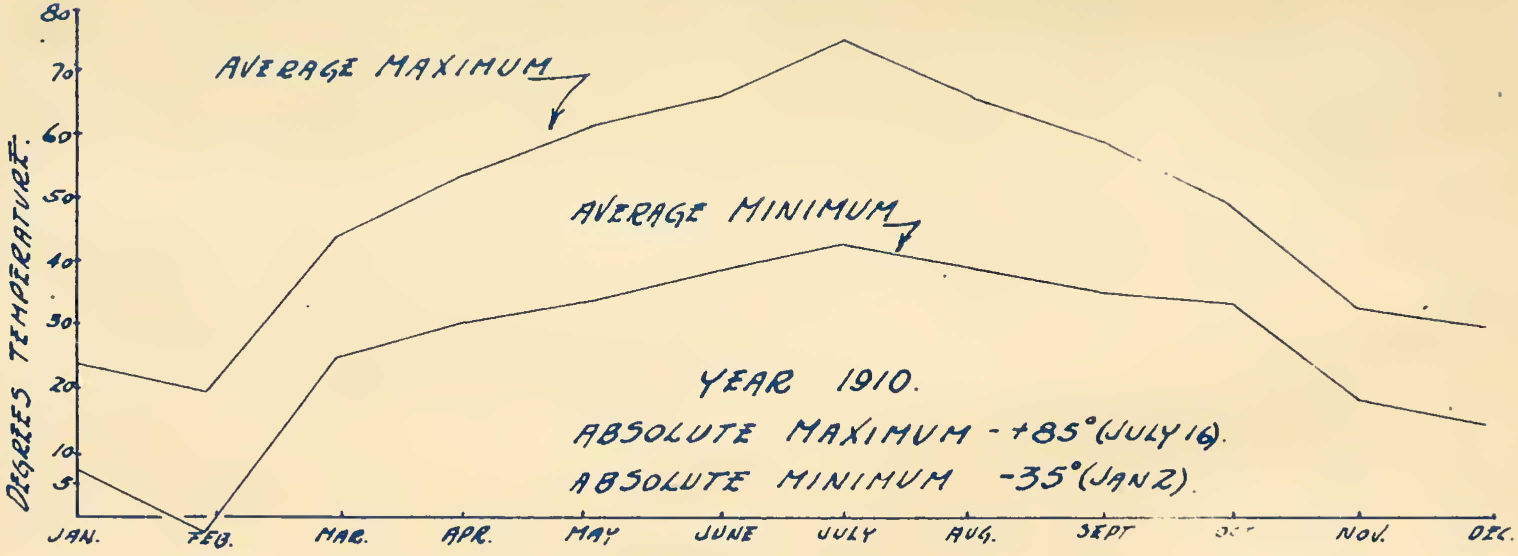
They require a license to construct and operate a Power Station and in this, they have been very liberal. The term of the license is for 21 years, renewable for three consecutive terms of 21 years each at a fixed fee payable annually and to be readjusted at the beginning of each term.

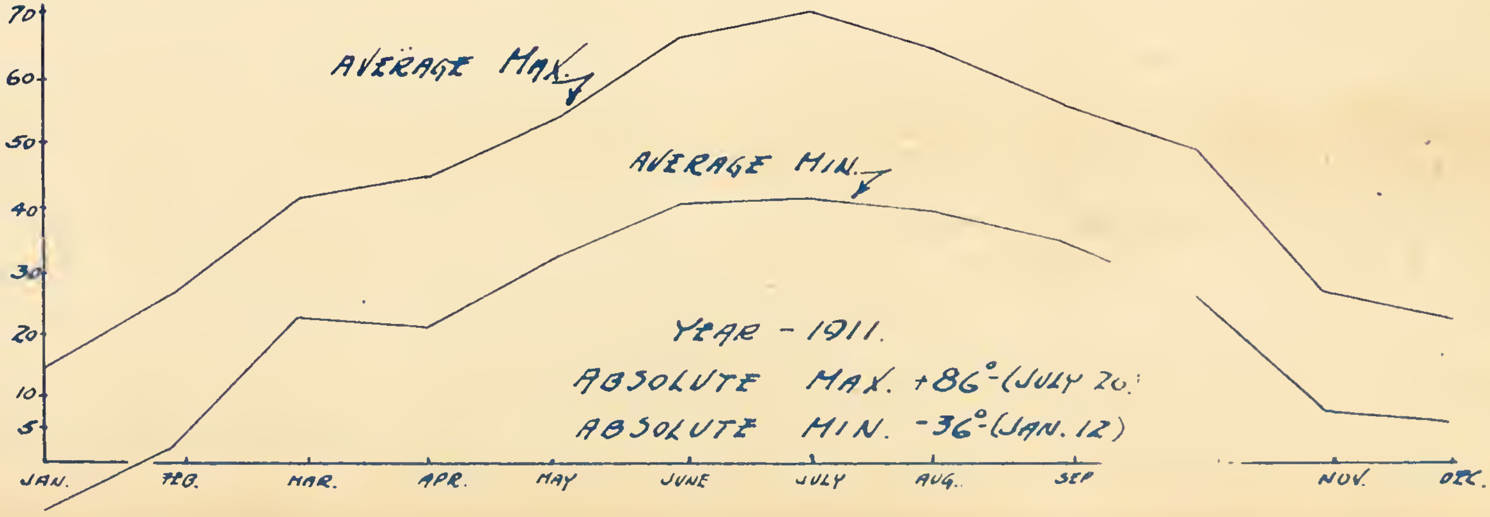
In conclusion, the writer wishes to express his belief in the feasibility of the herein proposed development at Bow Fort Falls, and believes that the project is very practical from every point of view, and that it would prove a good investment.

PLATE ·
PAGE ·

MEAN TEMPERATURE CURVES.

BOW FORT FALLS, ALBERTA, CANADA.





W.J. WIGNALL.

PLATE-
PAGE-

PRECIPITATION CURVES.

BOW FORT FALLS, ALBERTA, CANADA.

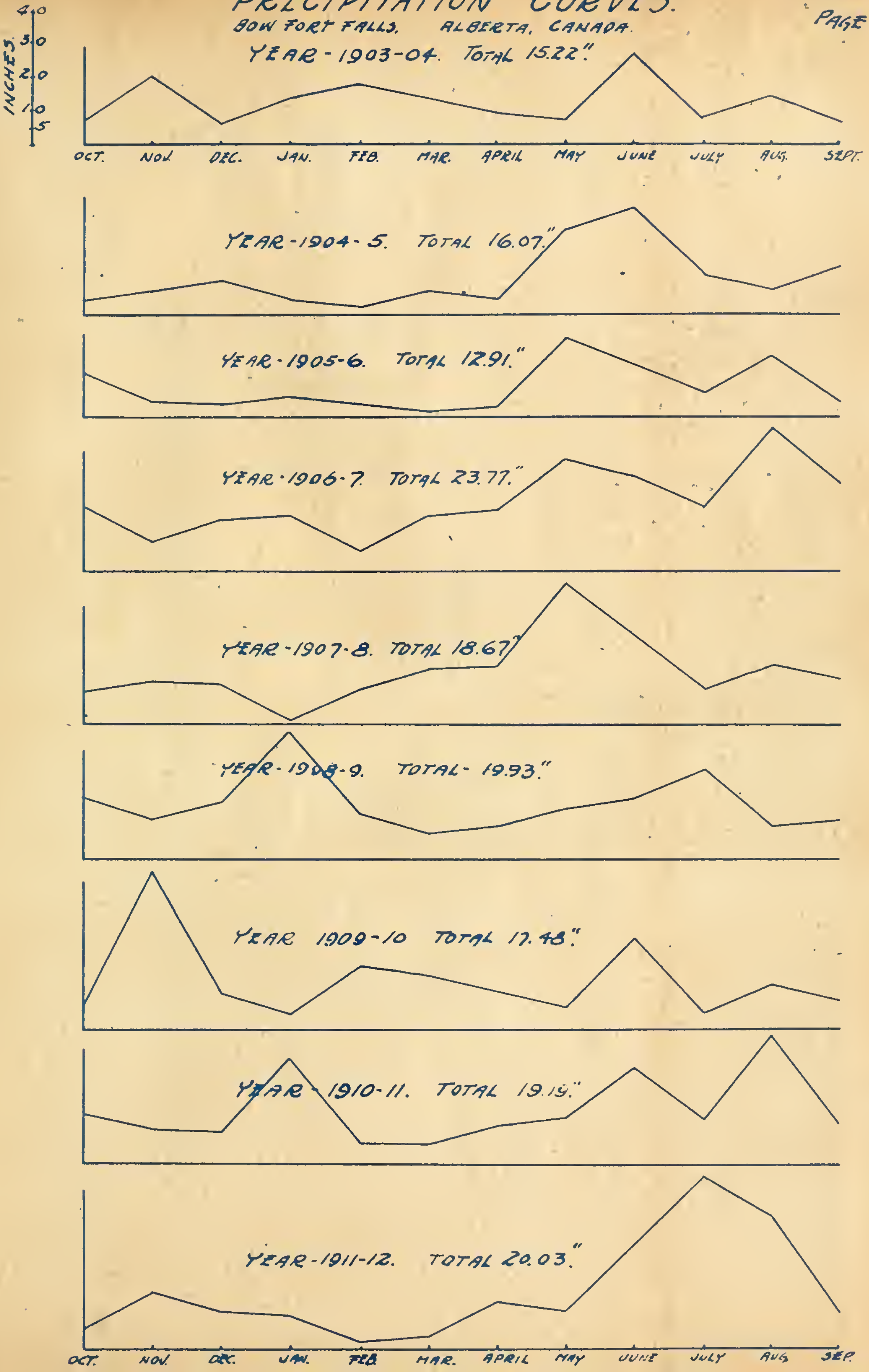
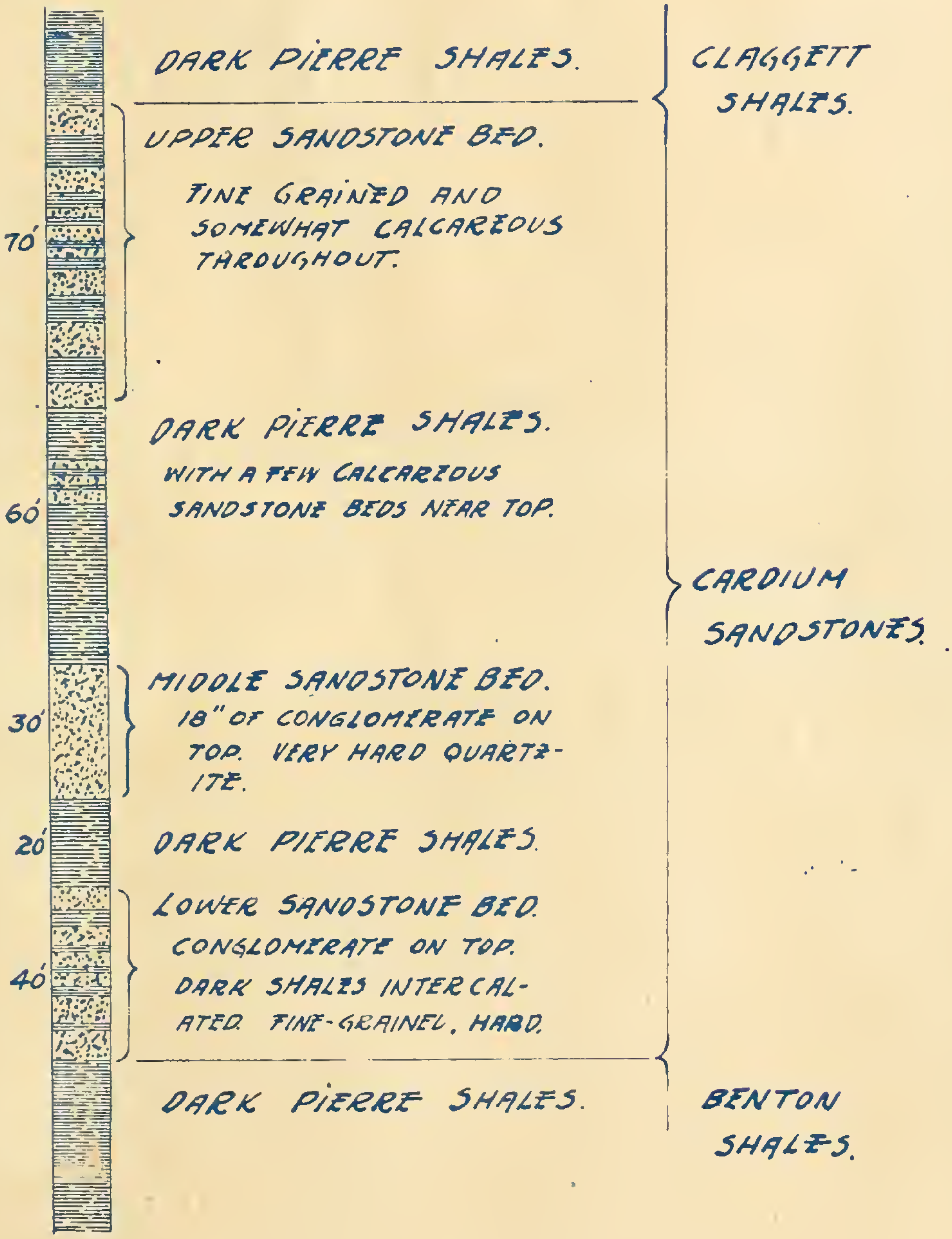
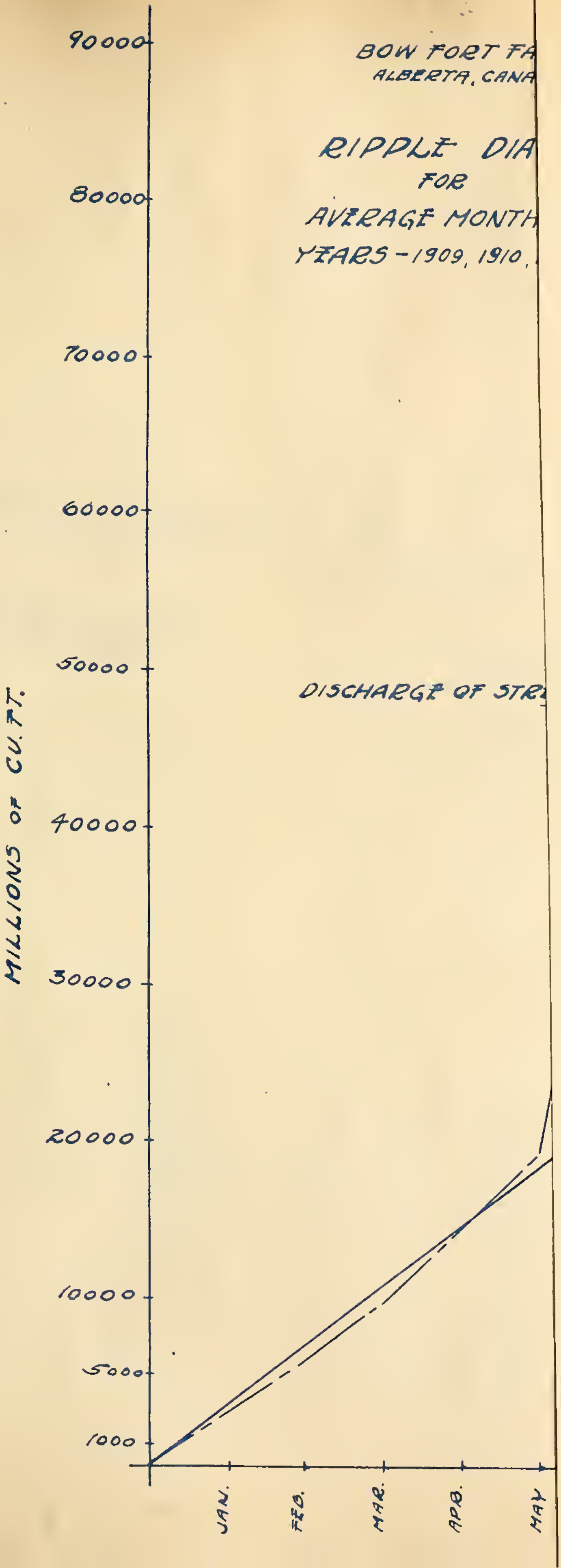


PLATE-
PAGE-

GEOLOGY OF SECTION
AT SITE OF PROPOSED DAM.
BOW FORT FALLS, ALBERTA, CANADA.



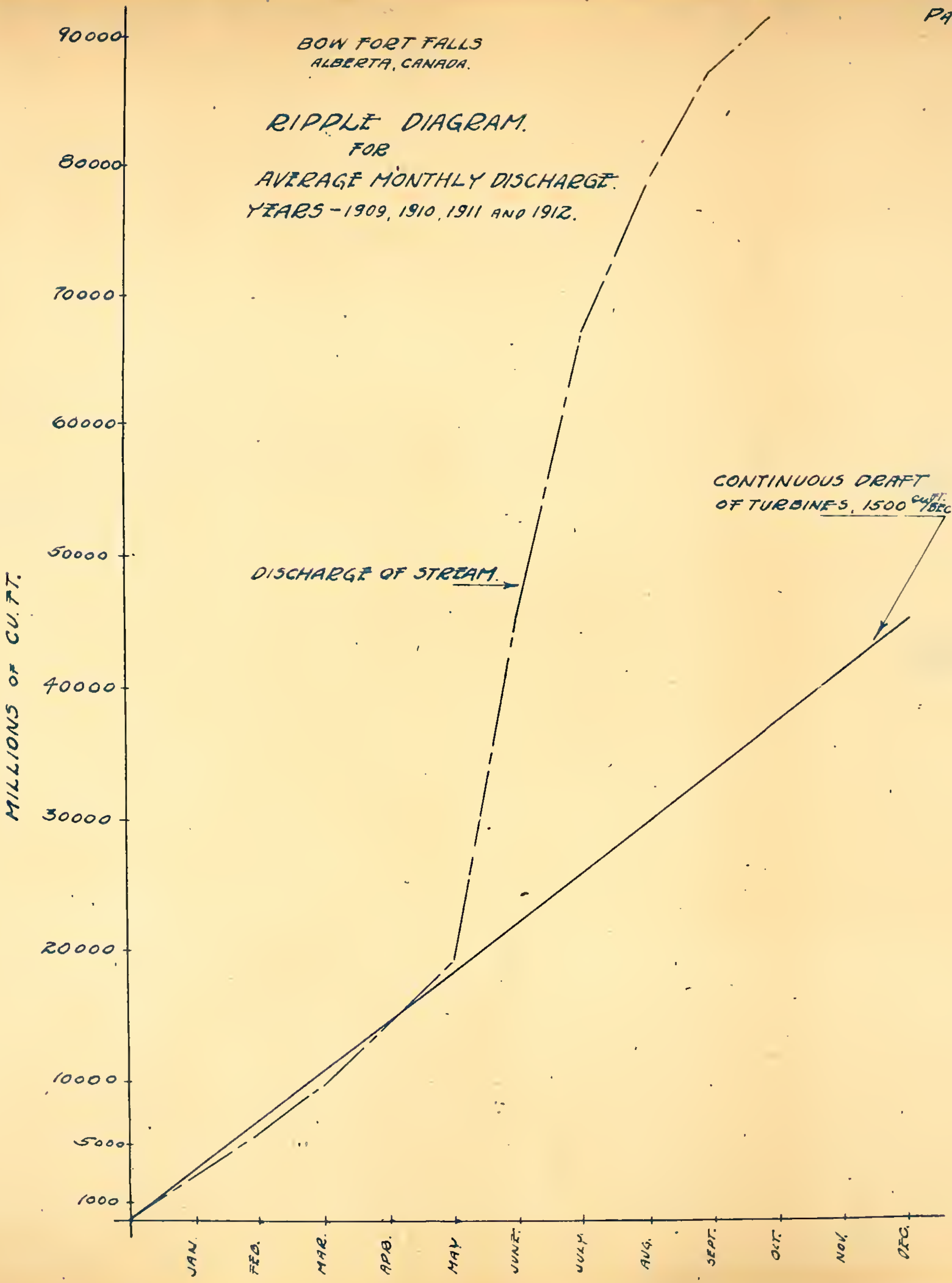
W.J. WIGNALL.



BOW FORT FA
ALBERTA, CANA

RIPPLE DIA
FOR
AVERAGE MONTH
YEARS - 1909, 1910,

PLATE 7.
PAGE



BOW FORT FALLS
ALBERTA, CANADA.

RIPPLE DIAGRAM.
FOR
AVERAGE MONTHLY DISCHARGE.
YEARS - 1909, 1910, 1911 AND 1912.

W.J. Wis

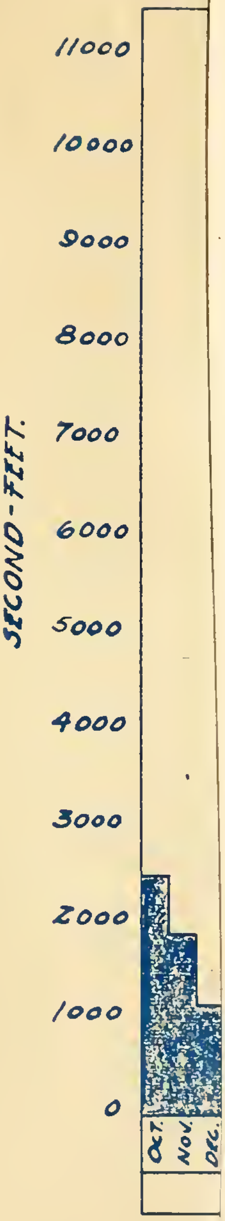
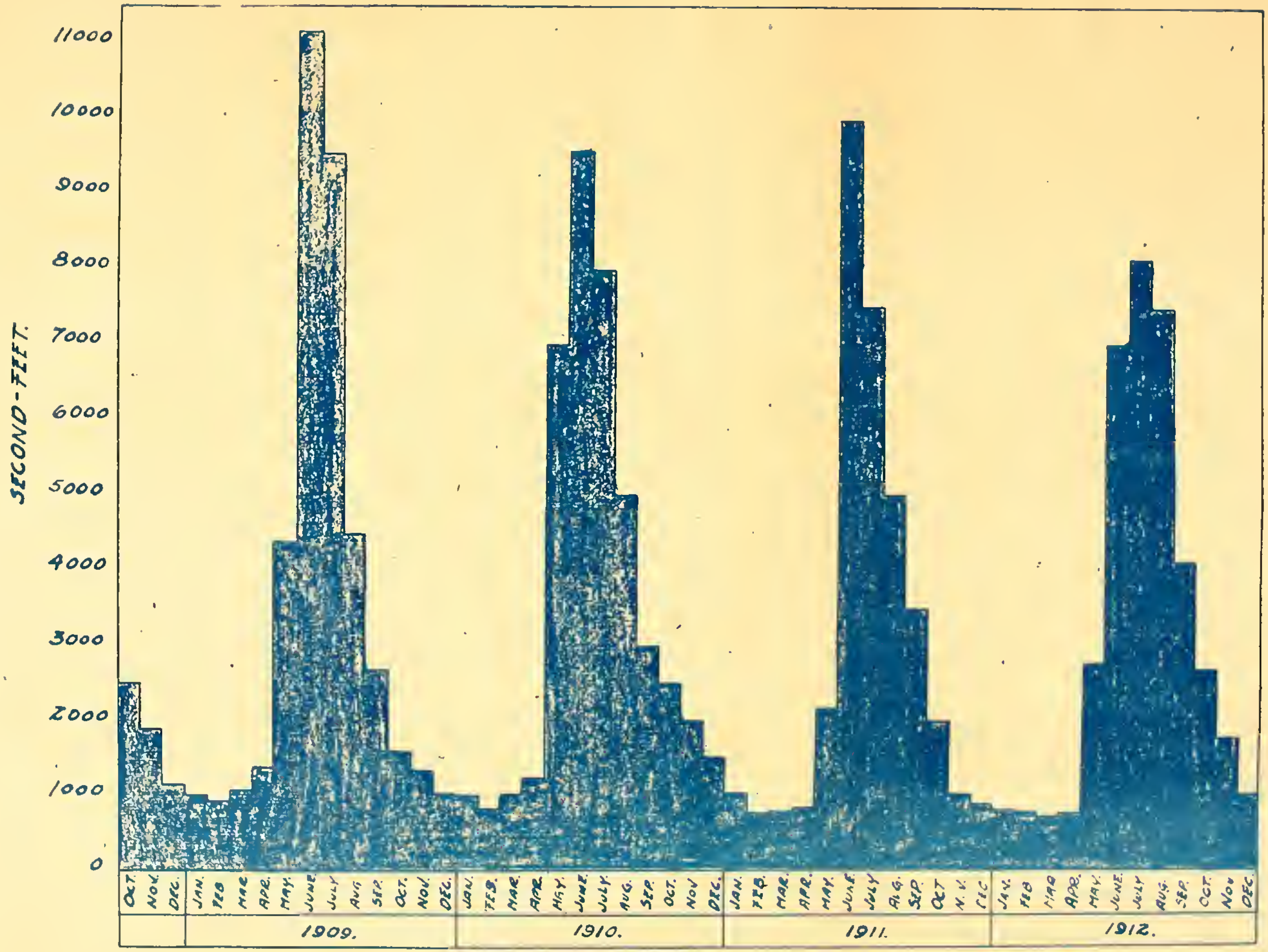

SECOND-FEET.
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
OCT.
NOV.
DEC.

PLATE
PAGE

BOW FORT FALLS, ALBERTA, CANADA.
DIAGRAM SHOWING MEAN MONTHLY DISCHARGE FROM
OCT. 1908 TO DEC. 1912.



W.J. WIGNALL.

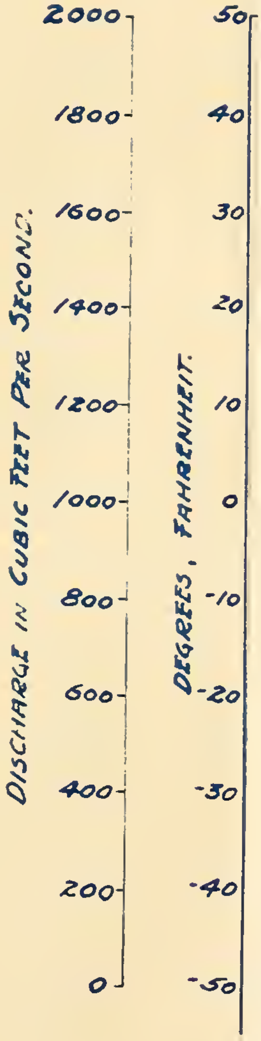
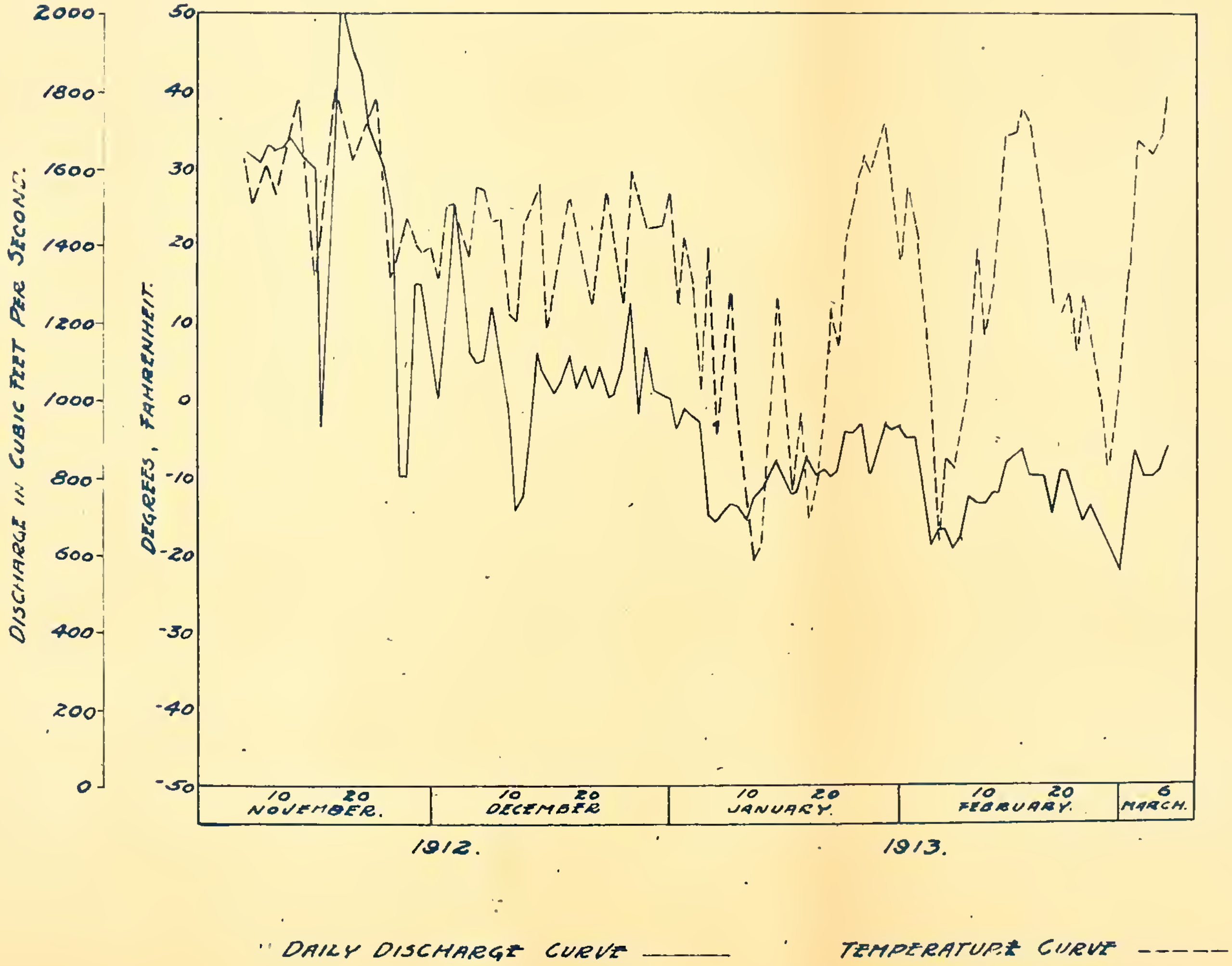
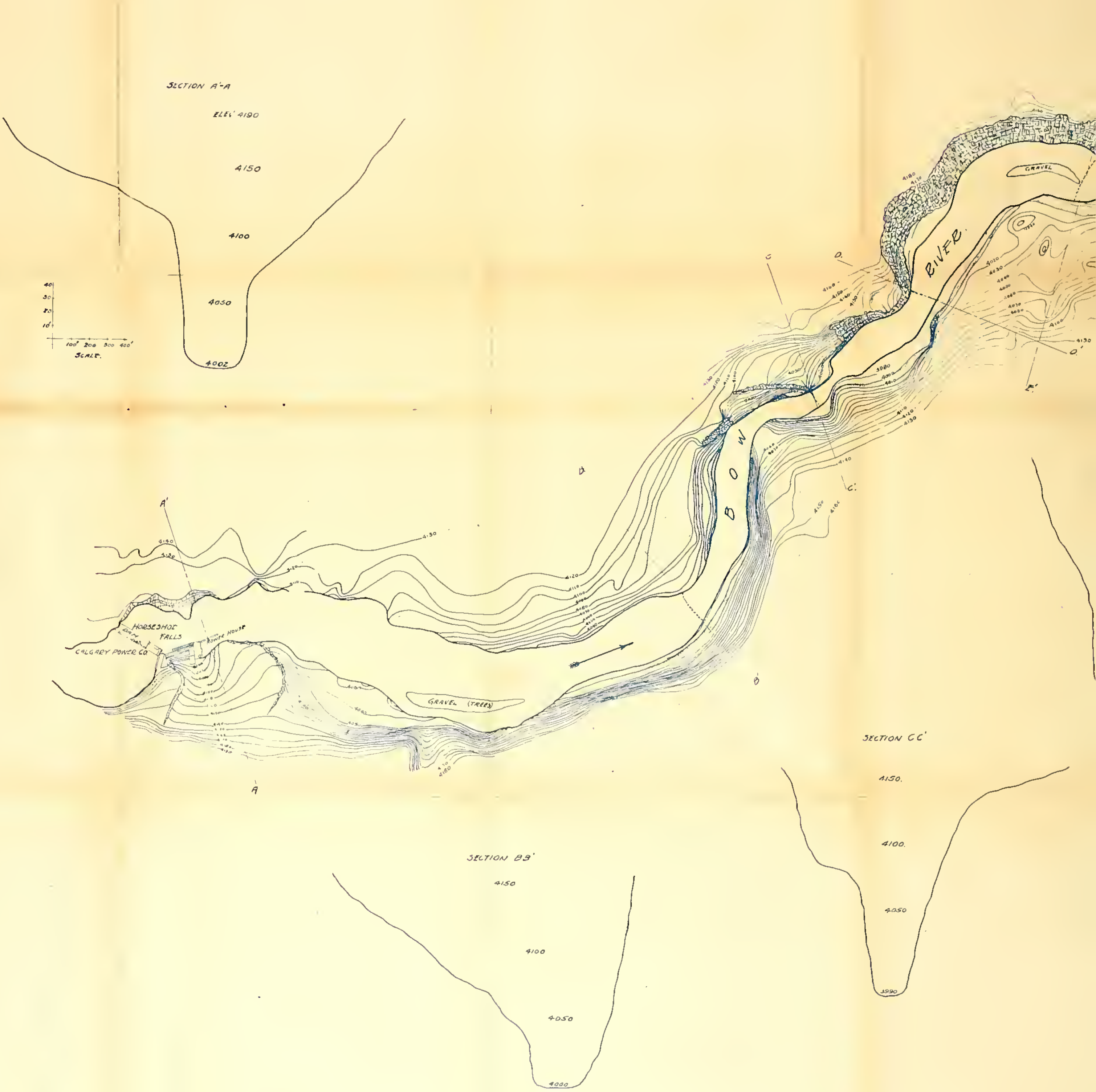

DISCHARGE IN CUBIC FEET PER SECOND.
2000
1800
1600
1400
1200
1000
800
600
400
200
0
DEGREES, FAHRENHEIT.
50
40
30
20
10
0
-10
-20
-30
-40
-50

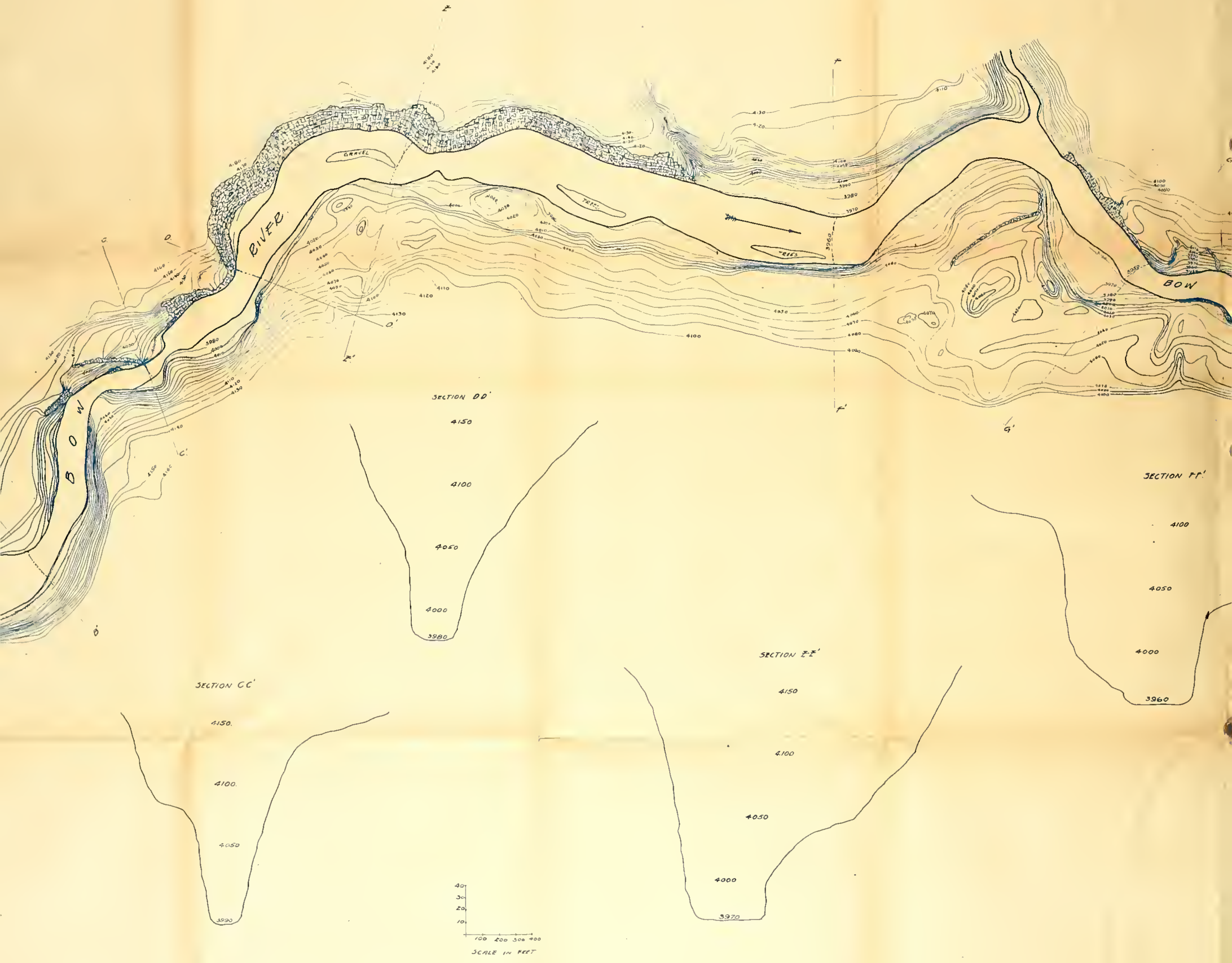
PLATE
PAGE

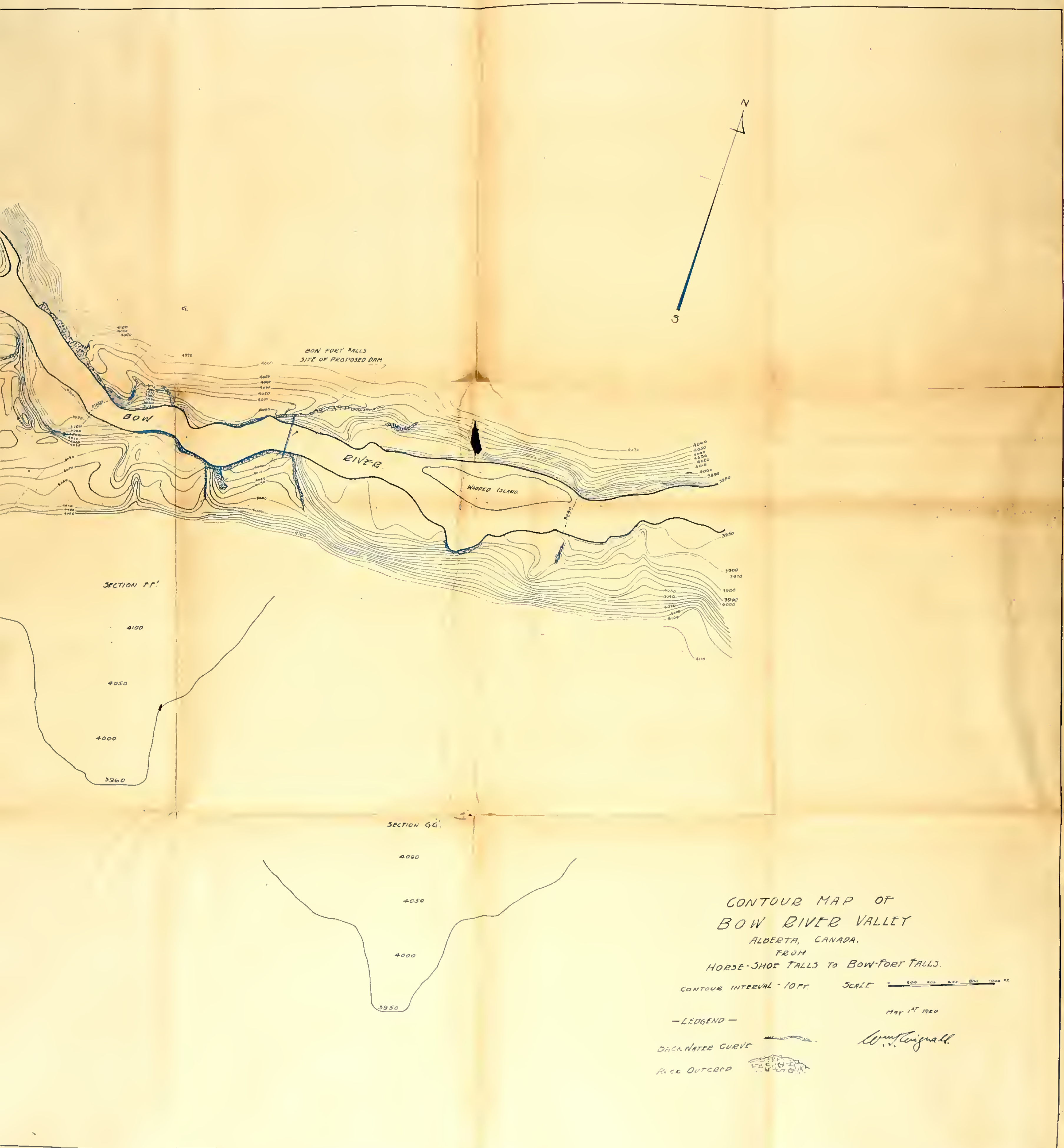
DAILY DISCHARGE
AND
DAILY TEMPERATURE
AT
BOW FORT FALLS, ALBERTA, CANADA.
FROM NOV. 1912 TO MAR. 1913.



W.J. WIGNALL


SECTION A'-A
ELEV. 4190
4150
4100
4050
4002
40
30
20
10
100' 200 300 400'
SCALE.
HORSESHOE
FALLS
DAM
POWER HOUSE
CALGARY POWER CO.
A'
A
B
B'
C
C'
D
D'
E'
4140
4130
4120
4110
GRAVEL (TREES)
GRAVEL
BOW
RIVER.
SECTION B-B'
4150
4100
4050
4000
SECTION C-C'
4150.
4100.
4050
3990


BOW
RIVER
BOW
GRAVEL
TREES
TREES
SECTION CC'
4150.
4100.
4050
3990
SECTION DD'
4150
4100
4050
4000
3980
SECTION EE'
4150
4100
4050
4000
3970
SECTION FF'
4100
4050
4000
3960
40
30
20
10
100 200 300 400
SCALE IN FEET



CONTOUR MAP OF
BOW RIVER VALLEY
ALBERTA, CANADA.
FROM
HORSE-SHOE FALLS TO BOW-FORT FALLS.

CONTOUR INTERVAL - 10 FT.
SCALE 0 200 400 600 800 1000 FT.

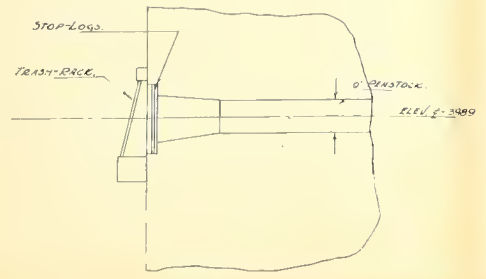
May 1st 1920

— LEDGEND —

BACK WATER CURVE

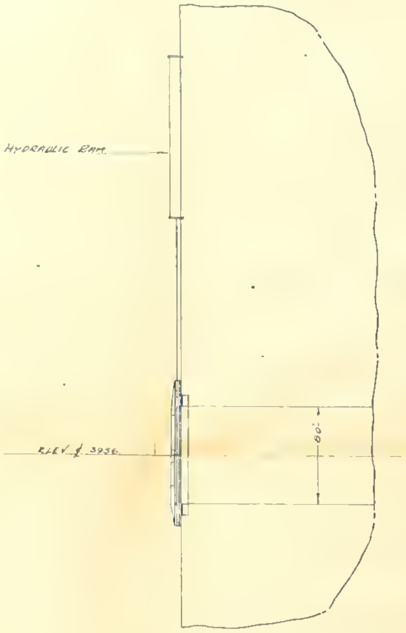
ROCK OUTCROP

Wm. J. Twignall



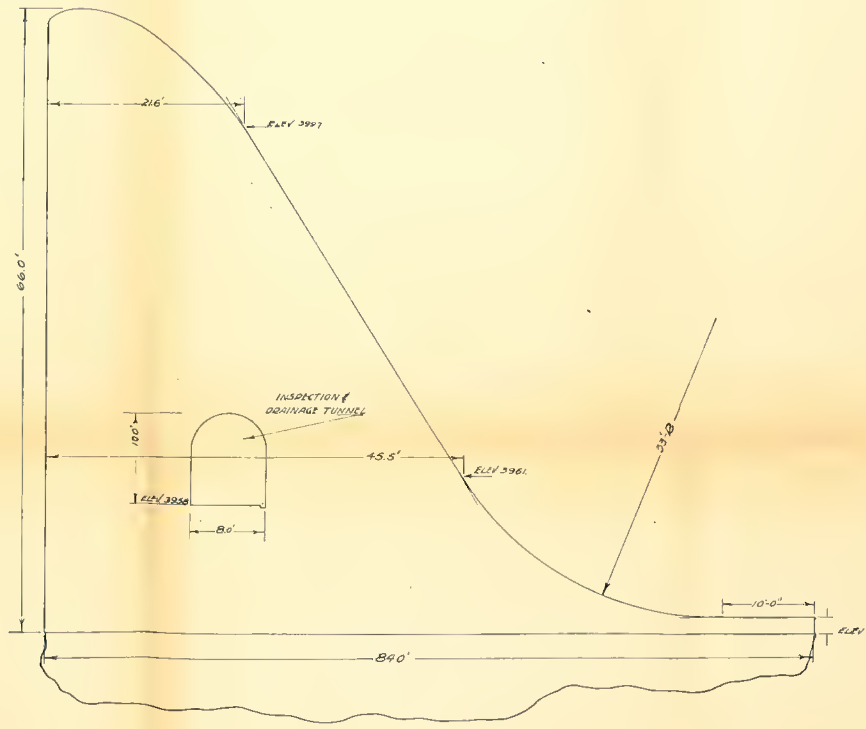
SECTION AT INTAKE

SCALE - 0 2 4 6 8 0 FEET



SECTION AT SLUICE-GATE.

SCALE · 0 1 2 3 4 5 FEET.



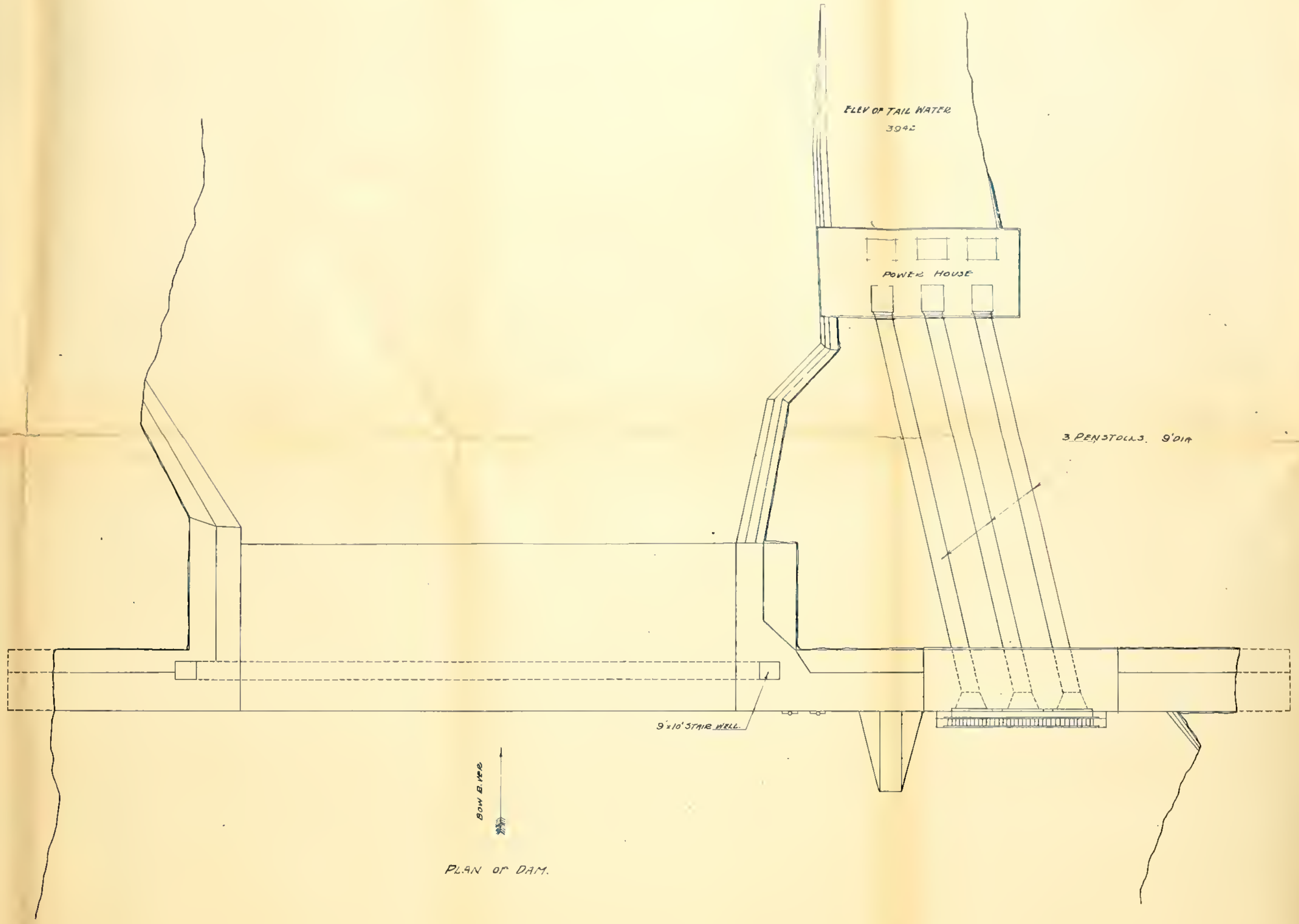
SPILLWAY SECTION.

SCALE - 0 1 2 3 4 5 FEET

PLAN AND DETAILS,
BOW FORT POWER PLANT.

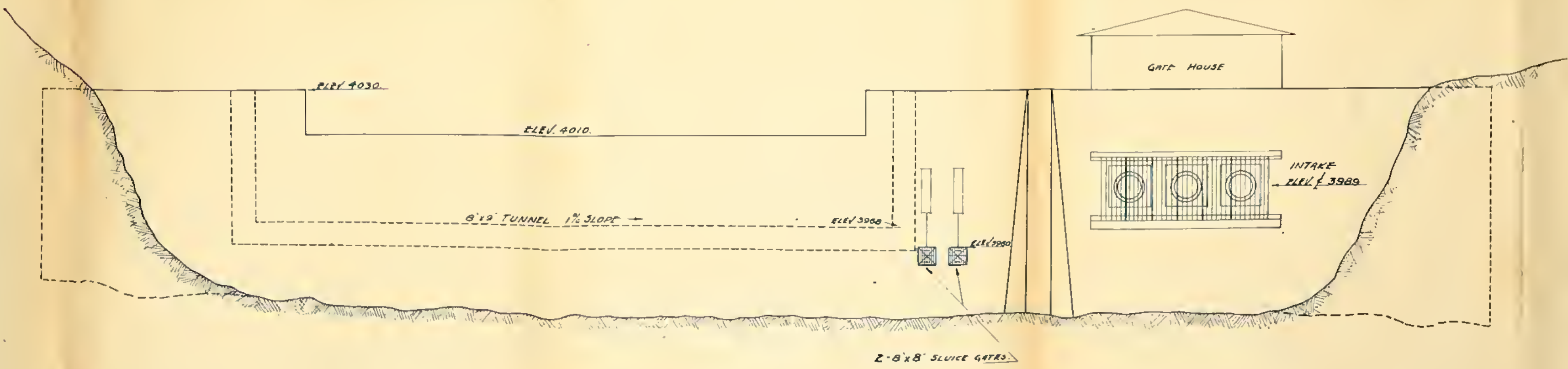
BOW FORT FALLS,
ALBERTA, CANADA.

MAY. 15TH 1920



PLAN OF DAM.

SCALE — 0 10 20 30 40 50 FEET.



UPSTREAM ELEVATION OF DAM.